CORRELATION OF THERMOMAGNETIC BEHAVIOR OF CARBONACEOUS CHONDRITES WITH CHEMICAL PETROGRAPHIC CLASSIFICATION

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(NASA-CR-141060) CORRELATION OF THERMOMAGNETIC BEHAVIOR OF CARBONACEOUS CHONDRITES WITH CHEMICAL PETROGRAPHIC CLASSIFICATION (Texas A&M Univ.) 10 p HC $3.25 CSCL 03B

N75-14669

Unclas
G3/91 05069

ABSTRACT

Some degree of correlation is noted between the thermomagnetic behavior of the carbonaceous chondrites and the chemical-petrographic classification scheme of Van Schmus and Hayes.

INTRODUCTION

Carbonaceous chondrites have been carefully classified into several divisions based on chemical, mineralogical, textural and petrologic observations (Wiik, 1956; Mason, 1963; Van Schmus and Wood, 1967; Van Schmus, 1969; and Van Schmus and Hayes, 1974). Utilizing the extensive measurements of natural remanent magnetization and magnetic susceptibility in more than 900 samples of meteorites, Gus'kova et al. (Pochtarev and Gus'kova, 1962; Gus'kova, 1969; Gus'kova and Pochtarev, 1969; and Gorshkov et al., 1972) demonstrated that these magnetic properties correlated with the chemical-petrologic classification of chondrites of Van Schmus and Wood (1967). More recently Brecher and Ranganayaki (1974) confirmed these correlations and extended the work to include other magnetic properties as well. A systematic study of the thermomagnetic properties on all the carbonaceous chondrites has recently been conducted (Larson et al. 1974; Watson et al., 1974; Herndon et al., 1974), and chemical and petrographic correlations existing among carbonaceous chondrites was most recently investigated by Van Schmus and Hayes (1974). Thus it appeared to be of interest to examine whether there exists a correlation between the thermomagnetic behavior and the chemical-petrographic data of the carbonaceous chondrites.

RESULTS AND DISCUSSION

It was found in the thermomagnetic analyses of all the carbonaceous chondrites that three categories were adequate to characterize most of the data. These three categories are for the purposes of this query best described as (1) those meteorites containing magnetite only as the principal magnetic mineral (2) those meteorites in which the thermomagnetic curve was characterized by a substantial increase in the saturation magnetization (J_s) during the course of the experiment and (3) those meteorites having a substantial metallic iron component (and frequently containing magnetite as well). Figs. 1-3 illustrates the thermomagnetic behavior of the three groups where the curve (Fig. 1) for the C1 chondrite Alais demonstrates the group (1) meteorites which contain magnetite only. Group (2) is illustrated in Fig. 2 with the curve for the C2 chondrite Boriskino which is representative of the category in which the saturation magnetization increases substantially during the course of the experiment. Note that in both Fig. 1 and 2 the saturation magnetization has become negligible by about 585°C, the Curie temperature for magnetite. Fig. 3, the J_s-T curve for the C3 chondrite Warrenton is characteristic of the third group which contains metallic iron. Note that the saturation magnetization does not drop to zero until about 770°C, the Curie point of metallic iron. There is evidence for the presence of magnetite as well in Warrenton as demonstrated by the inflection point which occurs at ~580°C. Thus for the purpose of correlating the thermomagnetic properties of the carbonaceous chondrites with the chemical-petrographic classifications we will place each of the carbonaceous chondrites into one of the three above categories. Table 1 lists all the carbonaceous chondrites with the Van Schmus-Hayes (1974) classification and the thermomagnetic category for comparison.

It is obvious that the thermomagnetic data do not correlate perfectly with the Van Schmus-Hayes classification. However, some correlation seems to exist and the following comments can be made.

(1) All C1 chondrites are similar thermomagnetically in that magnetite is the only strongly magnetic mineral present.

(2) Of the fourteen C2 chondrites, only three, (Essebi, Bells and Haripura) are not most characterized by a thermomagnetic curve which increases upon

cooling. Of those three, two deserve further mention. No analytical data is available on Bells; Haripura is not well defined between Van Schmus and Hayes (1974) chemical group A or B so that it's classification is questionable. Crescent and Pollen are noteworthy in that metallic iron is also indicated in their J_s-T curves; but here again, no chemical data is available for placement into chemical subdivisions A and B. Of the C2 chondrites, only Essebi is characterized as distinctly of the B chemical subdivision and by magnetite only in the J_s-T curve.

(3) Of the five C3(O) chondrites only Ornans is not characterized by the presence of metallic iron. Furthermore, if Al Rais and Renazzo, two type 2 Vigarano subtypes are included on the arbitrary basis that they appear to correlate with the chemical subgroup B, as do the C3(O) chondrites, then only Coolidge (C4), Crescent (C2) and Pollen (C2) are outside the group characterized by metallic iron, and no chemical data are available for Crescent or Pollen.

(4) The Vigarano subtypes are less distinct with regard to thermomagnetic character than the other categories and are also more complex chemically and petrographically than in the C2 and C3(O) chondrites (Van Schmus and Hayes, 1974). Here we see thermomagnetic groups 1 and 2 frequently with no obvious pattern between the two. However, Van Schmus and Hayes (1974) do note that "Allende, Grosnaja, Kaba, and Mokoia--are 'intermediate' in that they have properties of both type 2 and type 3 depending on the choice of criteria." Three of the four thermomagnetic group 1 in the Vigarano subtype are represented by Grosnaja, Kaba, and Mokoia and five of the remaining six are in thermomagnetic group 2.

In summary, though far from perfect, there does seem to exist some correlation between the thermomagnetic behavior of the carbonaceous chondrites and their chemical-petrological classification.

ACKNOWLEDGEMENTS

This research was supported in part by the National Aeronautics and Space Administration Grant NGR-44-001-152 and the Robert A. Welch Foundation Grant A-469. I am grateful to Dr. W. R. Van Schmus for his comments.

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Table 1. Comparison of the Thermomagnetic Characteristics of the Carbonaceous Chondrites with their Chemical-Petrographic Classification.

	CHONDRITE	VAN SCHMUS-HAYES SUBGROUP*	THERMOMAGNETIC CATEGORY+
C1			
	Alais	B	1
	Ivuna	B	1
	Orgueil	B	1
	Revelstoke	?#	1
	Tonk	B	1
C2			
	Boriskino	B	2
	Cold Bokkeveld	B	2
	Erakot	B	2
	Essebi	B	1
	Mighei	B	2
	Murchison	B	2
	Murray	B	2
	Narvapoli	B	2
	Nogoya	B	2
	Santa Cruz	B	2
	Bells	?#	1
	Crescent	?#	2,3
	Haripura	?	1
	Pollen	?#	2,3
C3(O)			
	Felix	B	3
	Kainsaz	?	3
	Lance'	B	3
	Ornans	B	1
	Warrenton	B	3
	Al Rais (2)	B**	3
	Renazzo (2)	B?**	3
C3(V)			
	Allende++	A	2
	Arch	?	2
	Bali	A	1
	Coolidge	A	2
	Efremovka++	A	2
	Grosnaja++	?*	1
	Kaba	A	1
	Leoville	A	2
	Mokoia++	A	1
	Vigarano	A	2

Table 1, Comparison of Thermomagnetic Characteristics, Cont'd.

CHONDRITE	VAN SCHMUS-HAYES SUBGROUP*	THERMOMAGNETIC CATEGORY+
C4		
Coolidge	A	3
Karoonda	?	2

*Van Schmus and Hayes (1974) note that "all C1, C2 and C3(O) chondrites correlate with the 'B' subdivision, whereas...'A' group belong to Vigarano subgroup." The A or B designation is taken from Table 3 of Van Schmus and Hayes.

+Refers here to the thermomagnetic characteristics displayed in Fig. 1, etc.

#No analytical data were available to classify in subgroups A or B.

⁑Van Schmus and Hayes (1974) note that "Although Al Rais and possibly Renazzo and Grosnaja appear to correlate with the 'B' subdivision, we believe they texturally definitely belong to the Vigarano subgroup." We have arbitrarily placed them with the C3(O) chondrites on the basis that (1) they differ from all other C2 chondrites and (2) the thermomagnetic properties correlate them with the 'B' subgroup of the C3(O) chondrites. This should not be taken to mean that Al Rais or Renazzo are C3(O) chondrites. They seem to be definitely type 2 Vigarano subgroup.

++Van Schmus and Hayes (1974) note that "...Allende, Grosnaja, Kaba, Mokoia--are 'intermediate' in that they have properties of both type 2 and type 3..." Note that three of the four thermomagnetic group 1 categories are from Grosnaja, Kaba, and Mokoia and that five of the six remaining meteorites are in thermomagnetic group 2.

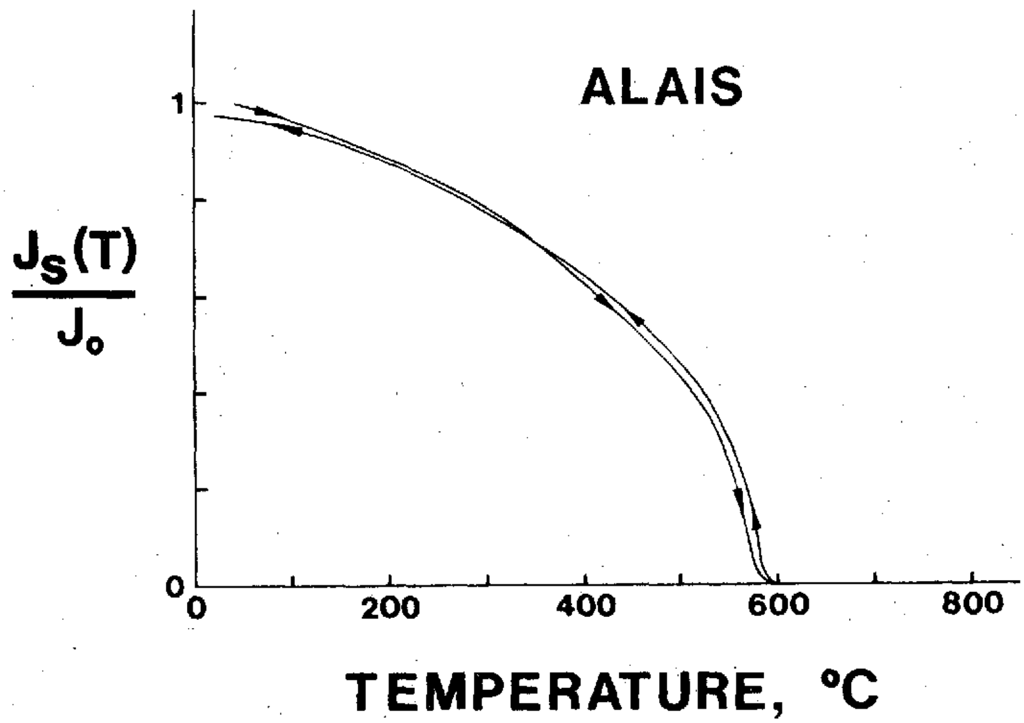

Fig. 1. The saturation magnetization vs. temperature (J_s-T) curve for the Alais C1 chondrite (Larson et al., 1974). This curve is characteristic of magnetite only as the magnetic mineral (Curie temperature ~585°C). Meteorites with this characteristic thermomagnetic behavior are placed in group 1 in Table 1.

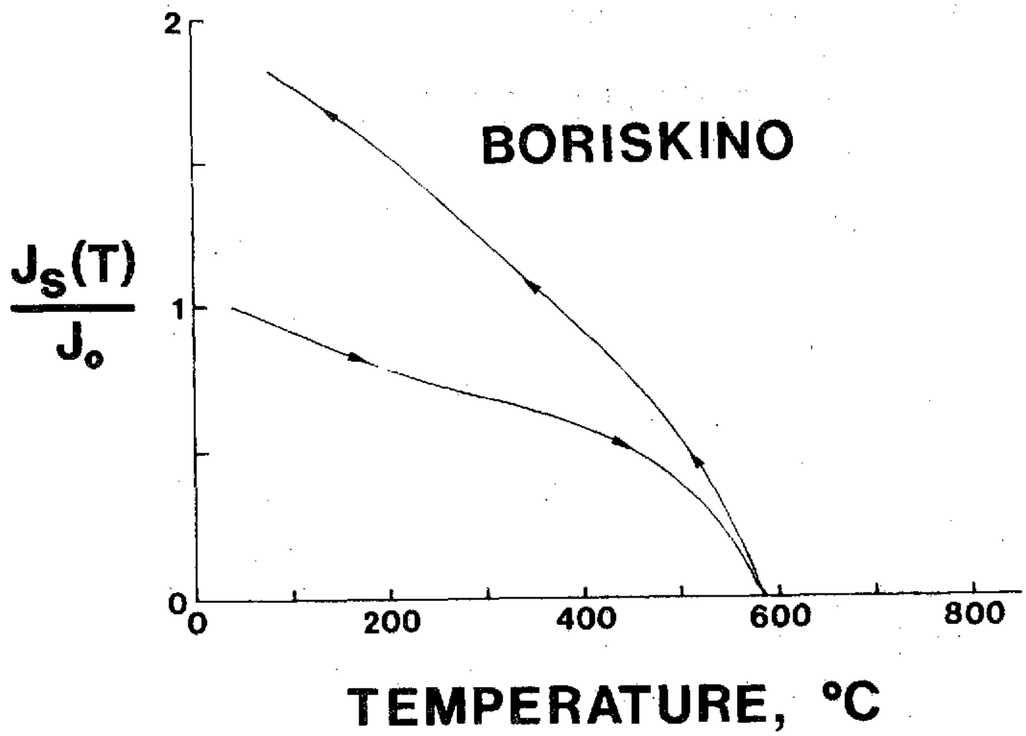

Fig. 2. The saturation magnetization vs. temperature (J_s-T) curve for the Boriskino C2 chondrite (Watson et al., 1974). This curve is most strongly characterized by the increase in saturation magnetization upon cooling. Meteorites displaying this thermomagnetic behavior are placed in group 2 in Table 1.

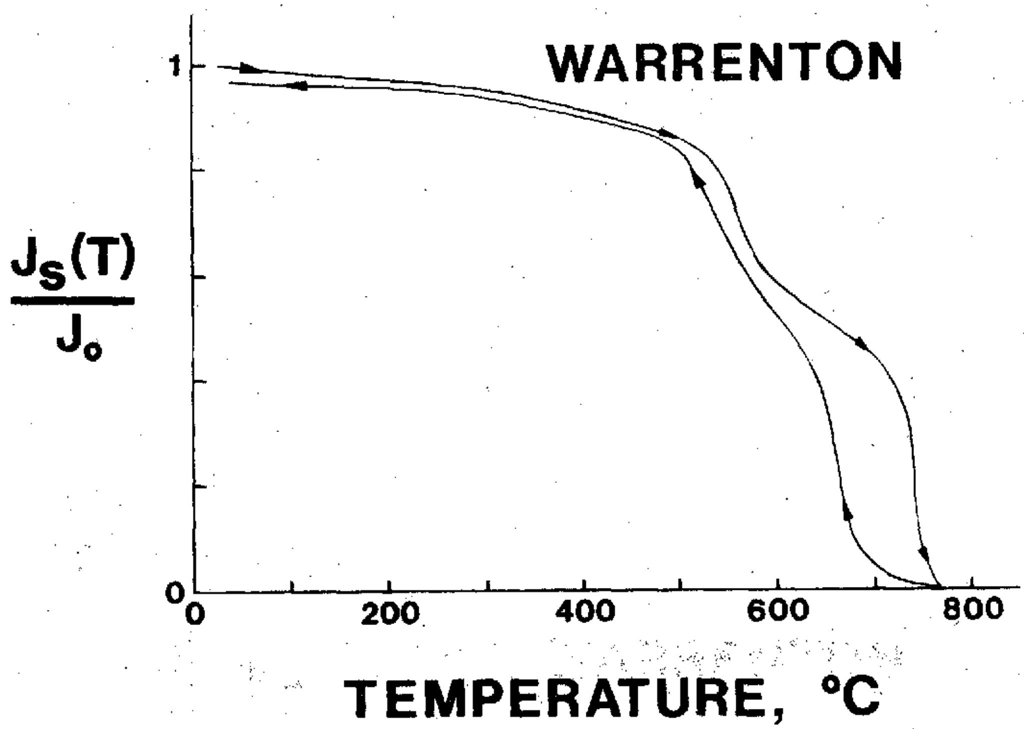

Fig. 3. The saturation magnetization vs. temperature (J_s-T) curve for the Warrenton C3 chondrite (Herndon et al., 1974). This curve is dominated by the presence of metallic iron (Curie temperature ~770°C). Meteorites with this thermomagnetic character are placed in group 3 in Table 1.

INTRODUCTION

Carbonaceous chondrites have been carefully classified into several divisions based on chemical, mineralogical, textural and petrologic observations (Wiik, 1956; Mason, 1963; Van Schmus and Wood, 1967; Van Schmus, 1969; and Van Schmus and Hayes, 1974). Utilizing the extensive measurements of natural remanent magnetization and magnetic susceptibility in more than 900 samples of meteorites, Gus'kova et al. (Pochtarev and Gus'kova, 1962; Gus'kova, 1969; Gus'kova and Pochtarev, 1969; and Gorshkov et al., 1972) demonstrated that these magnetic properties correlated with the chemical-petrologic classification of chondrites of Van Schmus and Wood (1967). More recently Brecher and Ranganayaki (1974) confirmed these correlations and extended the work to include other magnetic properties as well. A systematic study of the thermomagnetic properties on all the carbonaceous chondrites has recently been conducted (Larson et al. 1974; Watson et al., 1974; Herndon et al., 1974), and chemical and petrographic correlations existing among carbonaceous chondrites was most recently investigated by Van Schmus and Hayes (1974). Thus it appeared to be of interest to examine whether there exists a correlation between the thermomagnetic behavior and the chemical-petrographic data of the carbonaceous chondrites.

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